# APPENDIX D: LTBMU CLIMATE CHANGE TREND ASSESSMENT

## A summary of current trends and probable future trends in climate and climate- driven processes in the Lake Tahoe Basin and the neighboring Sierra Nevada

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**Climate Change Appendix Contents**

## I. Local trends in climate over the past century

The data presented in this section are derived from the 98-year weather station record from Tahoe City, California, on the north shore of Lake Tahoe (WRCC 2008), and the annual State of the Lake Report published by the UC-Davis Tahoe Environmental Research Center (TERC 2008). Spatial data are also presented from the PRISM climate dataset, which extrapolates weather station records to the landscape for all years beginning in the late 19th century (Daly et al. 1994, PRISM 2010).

### Temperature

Over the last century, mean annual temperature in the Lake Tahoe Basin (LTB) has risen by about two degrees Fahrenheit (Fig. D1). This trend is driven by a highly significant increase in mean minimum (i.e., nighttime) temperatures, which have risen by four degrees F since 1910. For the first time on record, the annual average of the monthly mean minima is now above the freezing point (Fig. 1). At the beginning of the last century, seven to eight months in a year could be expected to have average nighttime temperatures that fell below freezing. Today the average is closer to six months, and the trend is strongly downward. The average number of days in a year on which the average air temperature remains below freezing has dropped by 27 days since 1910 (78 to 51; TERC 2008). The LTB rise in nighttime temperatures is higher than in most California locations and may be linked to the thermal mass of Lake Tahoe, whose surface waters have increased in temperature by one degree F in only the last 25 years (TERC 2008).

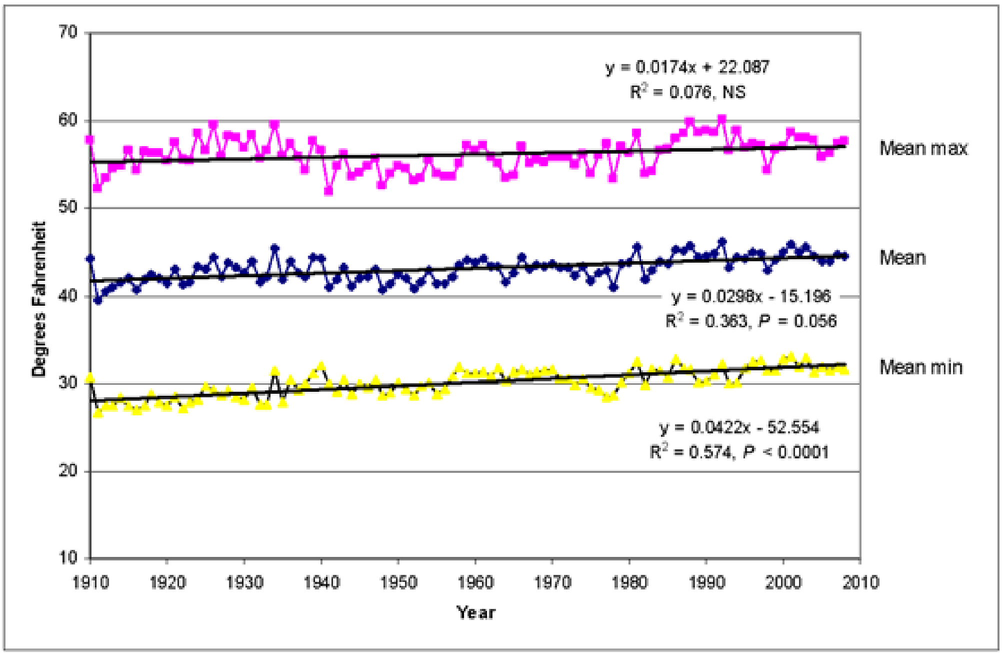


**Figure D1. Annual mean, mean maximum, and mean minimum temperatures at Tahoe City, California, 1910-2008.**
*Trend lines fit with simple linear regression, no transformations employed. Data from WRCC 2008.*

## Precipitation

The 98-year trend in LTB precipitation is shown in Fig. D2. Average annual precipitation has risen by almost 7 inches per year over the period, but there is very high interannual variability, such that the value predicted by the regression line in Fig. D2 is rarely representative of the actual annual mean. Of the months of the year, only August showed an even marginally significant increase in precipitation over the period of record (R2 = 0.034, P = 0.067), with the average August precipitation rising from about 0.2 to about 0.4 inches (1% of annual precipitation). There were no significant increases in precipitation by season, and the distribution of precipitation across the year has remained similar through the record (WRCC 2008). The 5-yr coefficient of variation in annual precipitation is rising over time (Fig. D3), which demonstrates that year-to-year variability in precipitation has increased over the course of the last century. Further evidence of high variability in recent annual precipitation sums can be seen in the last quarter-century of records: nine of the 20 wettest years have occurred since 1980, and two of the top three since 1995, but 2007 and 2008 are among the ten driest years on record. Mean annual snowfall has not changed significantly over the last century (TERC 2008), but when combined with the precipitation trend, it is obvious that the proportion of precipitation falling as snow (vs. rain) is dropping. At the beginning of the last century, about 54% of precipitation fell as snow, today the average is about 34%. Streamflow data show that peak snowmelt in the LTB is occurring 2½ weeks earlier today than at the beginning of the 1960's, when the record began (TERC 2008).

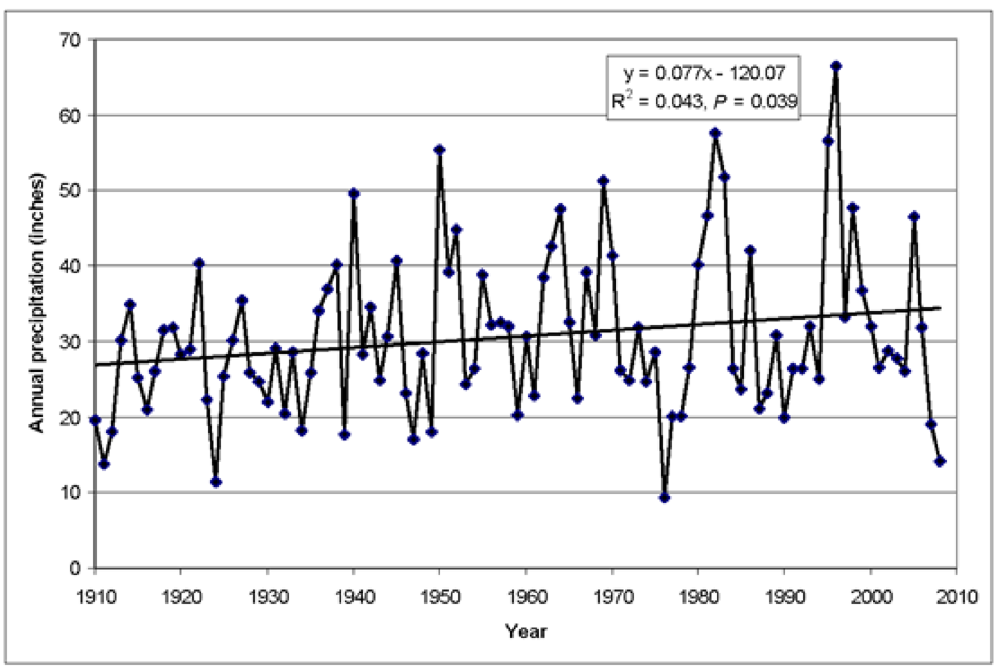


**Figure D2. Mean annual precipitation at Tahoe City, California, 1910-2008. Data from WRCC 2008.**

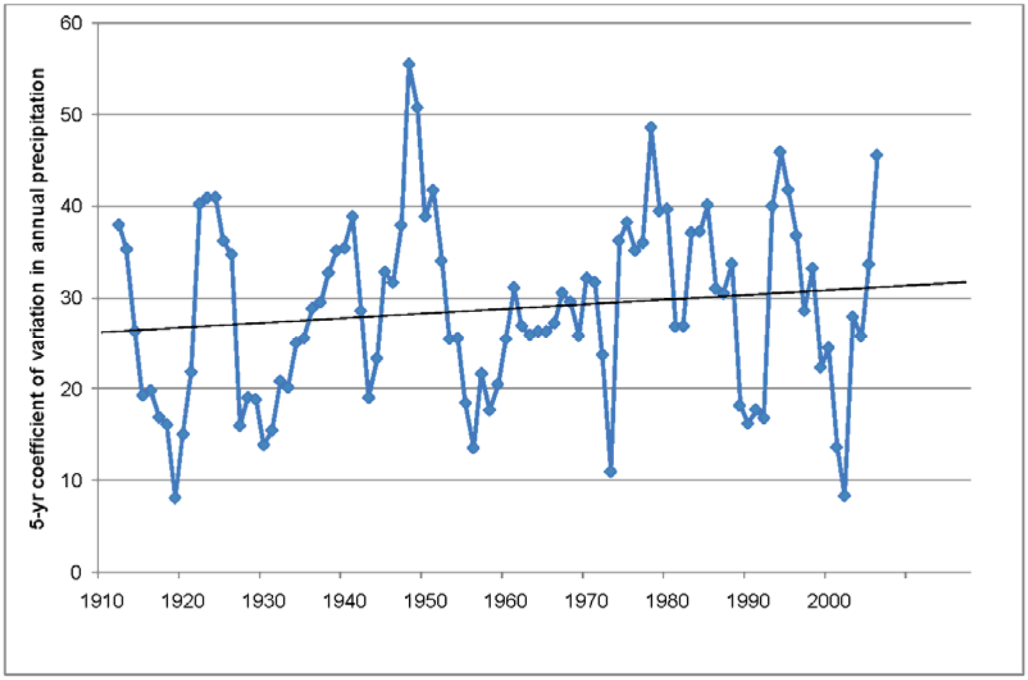


**Figure D3. Five-year coefficients of variation in annual precipitation at Tahoe City, California, 1910-2008.** *Data from WRCC 2008.*

Snowpack measurements show a strong downward trend across northern California over the last ½ century, with the Sierra Nevada near Lake Tahoe experiencing decreases of >70% in snow water equivalent in many places (Fig. D4).

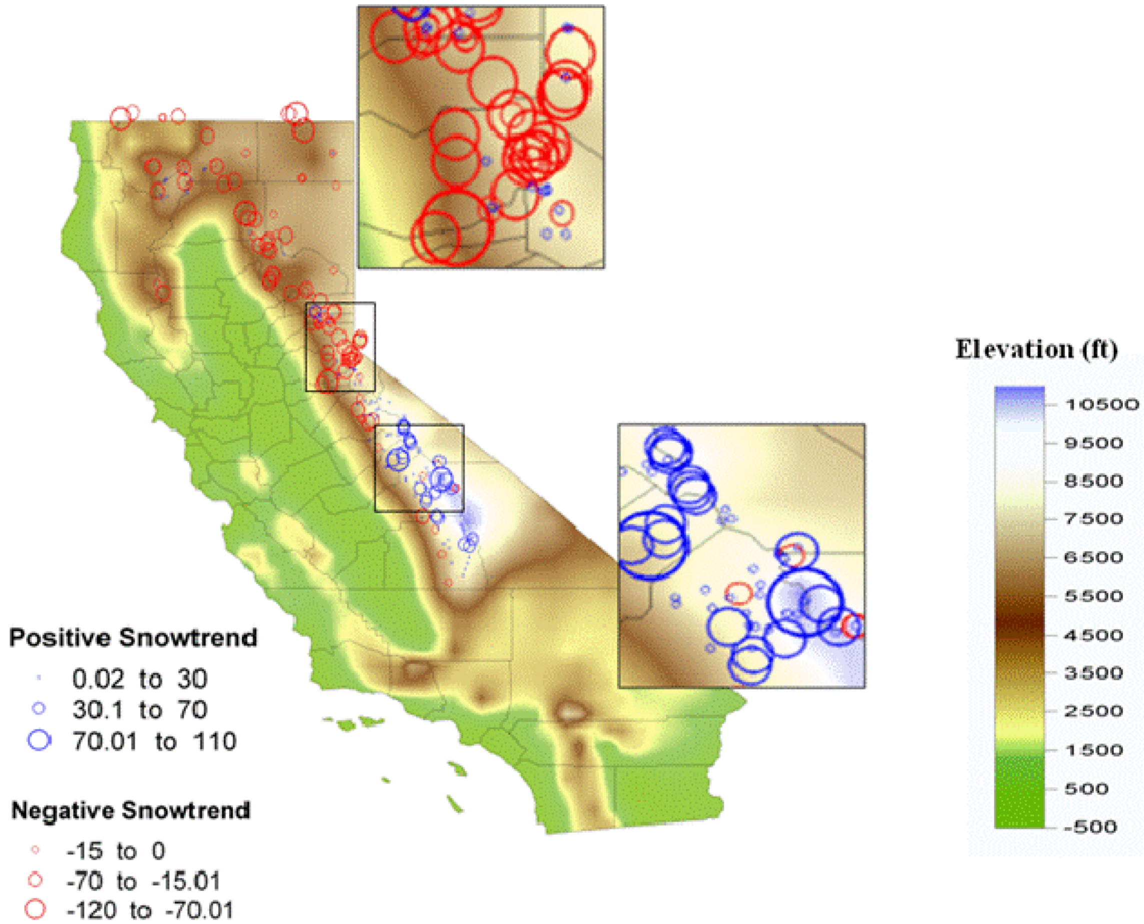


**Figure D4. Trends in the amount of water contained in the snowpack ("snow water equivalent") on April 1, for the period 1950-1997.**
*Red circles indicate percent decrease in snow water, blue circles indicate increase in snow water. From Moser et al. (2009).*

The PRISM dataset shows that the area of the Sierra Nevada adjoining Lake Tahoe has experienced substantial increases in both temperature and precipitation over the last ¾ century (Fig. D5). This agrees with the trends from the Tahoe City station, but hides substantial variation among specific weather station sites.

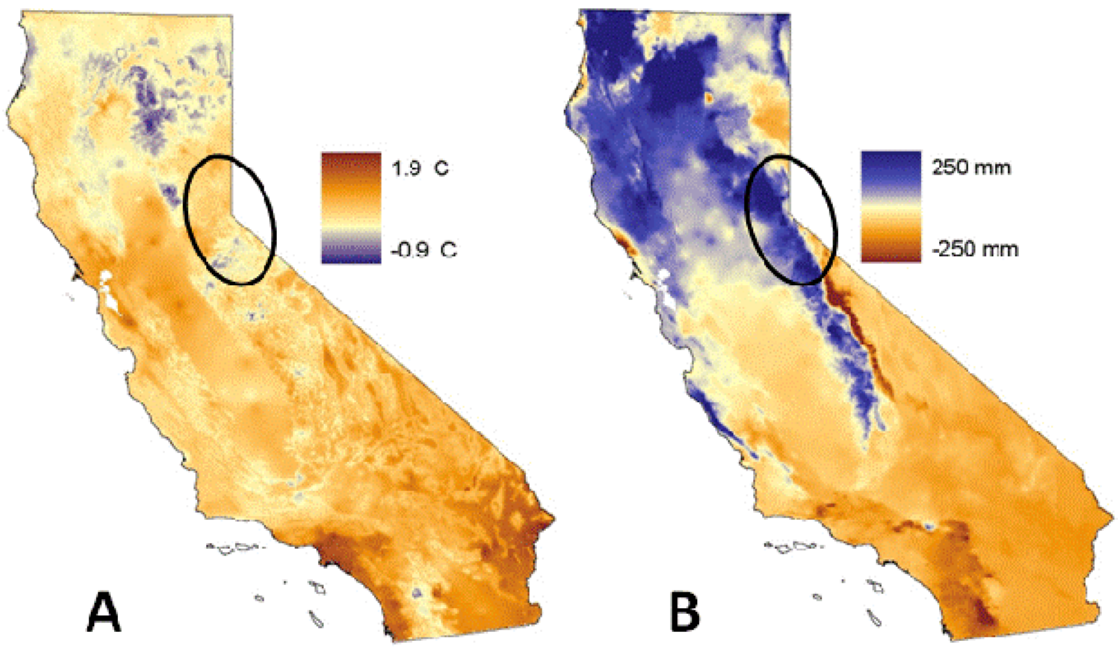


**Figure D5. Spatial differences in mean annual temperature (A), and mean annual precipitation (B) between the 1930's and 2000's, as derived by the PRISM climate model.**
*The LTBMU is found in the middle of the circled area. Both temperatures and precipitation have risen across most of the circled area, although precipitation has generally dropped east of the Sierra Nevada crest. Graphic courtesy of S. Dobrowksi, Univ. of Montana.*

## II. Regional trends over the last century linked to climate change

### Hydrology

Stewart et al. (2005) showed that the onset of spring thaw in most major streams in the central Sierra Nevada occurred 5-30 days earlier in 2002 than in 1948, and peak streamflow (measured as the center of mass annual flow) occurred 5-15 days earlier. During the same period, March flows in the studied streams were mostly higher by 5-20%, but June flows were mostly lower by the same amount; overall spring and early summer streamflow was down in most studied streams. Rising winter and spring temperatures appear to be the primary driver of these patterns (Stewart et al. 2005). Coats (2010) examined the shift in snowmelt timing in the Lake Tahoe Basin between 1972 and 2007 and found that the timing of the spring snowmelt peak occurred about two weeks earlier in 2007 than in 1972.

### Forest Fires

Data on forest fire frequency, size, total area burned, and severity all show strong increases in the Sierra Nevada over the last two to three decades. Westerling et al. (2006) showed that increasing frequencies of large fires (>1000 acres) across the western United States since the 1980's were strongly linked to increasing temperatures and earlier spring snowmelt. The Sierra Nevada was one of two geographic areas of especially increased fire activity, which Westerling et al. (2006) ascribed to an interaction between climate and increased fuels due to fire suppression. Westerling et al. (2006) also identified the Sierra Nevada has being one of the geographic regions most likely to see further increases in fire activity due to future increases in temperature. Miller et al. (2009) showed that mean and maximum fire size, and total burned area in the Sierra Nevada have increased strongly between the early 1980's and 2007. Climatic variables explain very little of the pattern in fire size and area in the early 20th century, but 35-50% of the pattern in the last 25 years. The mean size of escaped fires in the Sierra Nevada was about 750 acres until the late 1970's, but the most recent ten-year average has climbed to about 1100 acres. Miller et al. (2009) also showed that forest fire severity (a measure of the effect of fire on vegetation) rose strongly during the period 1984-2007, with the pattern centered in middle elevation conifer forests. Fires at the beginning of the record burned at an average of about 17% high (stand-replacing) severity, while the average for the last ten-year period was 30%. Miller et al. (2009) found that both climate change and increasing forest fuels were necessary to explain the patterns they analyzed.

## Forest Structure

Fire suppression has been practiced as a federal policy since 1935. Pre-Euroamerican fire frequencies in high elevation forests such as red fir (>50 years in most places) and subalpine forest (>100 years) were long enough that fire suppression has had little or no impact on ecological patterns or processes (Miller et al. 2009). Higher elevation forests are also much more remote, less likely to have economic uses, and are often protected in Wilderness Areas and National Parks, so impacts by logging or recreation use are minimal. Subalpine tree growth has been shown to be strongly influenced by higher precipitation and warm summers (Graumlich 1991). Long-term changes in stand structure in higher elevation forests are thus more likely to represent responses to changes in exogenous factors like climate.

In the early 1930's, the Forest Service mapped vegetation in the Lake Tahoe Basin and neighboring National Forests, and sampled thousands of vegetation plots (Wieslander 1935). Bouldin (1999) compared the Wieslander plots with the modern FIA inventory and described changes in forest structure. In red fir forest, Bouldin (1999) found that densities of young trees had increased by about 40% between 1935 and 1992, but densities of large trees had decreased by 50% during the same period. In old-growth stands, overall densities and basal areas were higher, and the number of plots in the red fir zone dominated by shade-tolerant species increased at the expense of species like Jeffrey pine and western white pine. In old-growth subalpine forests, Bouldin (1999) found that young mountain hemlock was increasing in density and basal area while larger western white pine was decreasing. In whitebark pine stands, overall density was increasing due to increased recruitment of young trees, but species composition had not changed. Lodgepole pine appears to be responding favorably to increased warming and/or increased precipitation throughout the subalpine forest.

Bouldin (1999) also studied mortality patterns in the 1935 and 1992 datasets. He found that mortality rates had increased in red fir, with the greatest increases in the smaller size-classes. At the same time, in subalpine forests, lodgepole pine, western white pine, and mountain hemlock all showed decreases in mortality. The subalpine zone was the only forest type Bouldin (1999) studied where mortality had not greatly increased since the 1935 inventory. This suggests that climate change (warming, plus steady or higher precipitation) is actually making conditions better for some tree species in this stressful environment. Dolanc et al. (2010) recently completed a study that resampled Wieslander plots in the subalpine zone between Yosemite National Park and the Lake Tahoe Basin. Corroborating Boulding (1999), they found that growing conditions in the subalpine zone were probably better today than in the 1930's, as the density of small trees of almost all species had increased greatly in the 75 year period. Dolanc et al.'s (2010) direct plot-to-plot comparison also found that mortality of large trees had decreased density of the subalpine forest canopy, but the overall trend was for denser forests with no apparent change in relative tree species abundances.

Van Mantgem et al. (2009) recently documented widespread increases in tree mortality in old- growth forests across the west, including in the Sierra Nevada. Their plots had not experienced increases in density or basal area during the 15-40 year period between first and last census. The highest mortality rates were documented in the Sierra Nevada, and in middle elevation forests (3300-6700 feet). Higher elevation forests (>6700 feet) showed the lowest mortality rates, corroborating the Bouldin (1999) findings. Van Mantgem et al. (2009) ascribed the mortality patterns they analyzed to regional climate warming and associated drought stress. Comparisons of the 1930's Wieslander vegetation inventories and map with modern vegetation maps and inventories show large changes in the distribution of many Sierra Nevada vegetation types over the last 70-80 years (Fig. D6a, D6b; Bouldin 1999, Moser et al. 2009, Thorne and Safford, unpub. data). The principal trends are (1) loss of yellow pine dominated forest, (2) increase in the area of forest dominated by shade-tolerant conifers (especially fir species), (3) loss of blue oak woodland, (4) increase in hardwood dominated forests, (5) loss of subalpine and alpine vegetation, and (6) expansion of subalpine trees into previous permanent snowfields. Trends (4) through (6) appear to have a strong connection to climate warming, while trends (1) through (3) are mostly the product of human management choices, including logging, fire suppression, and urban expansion.

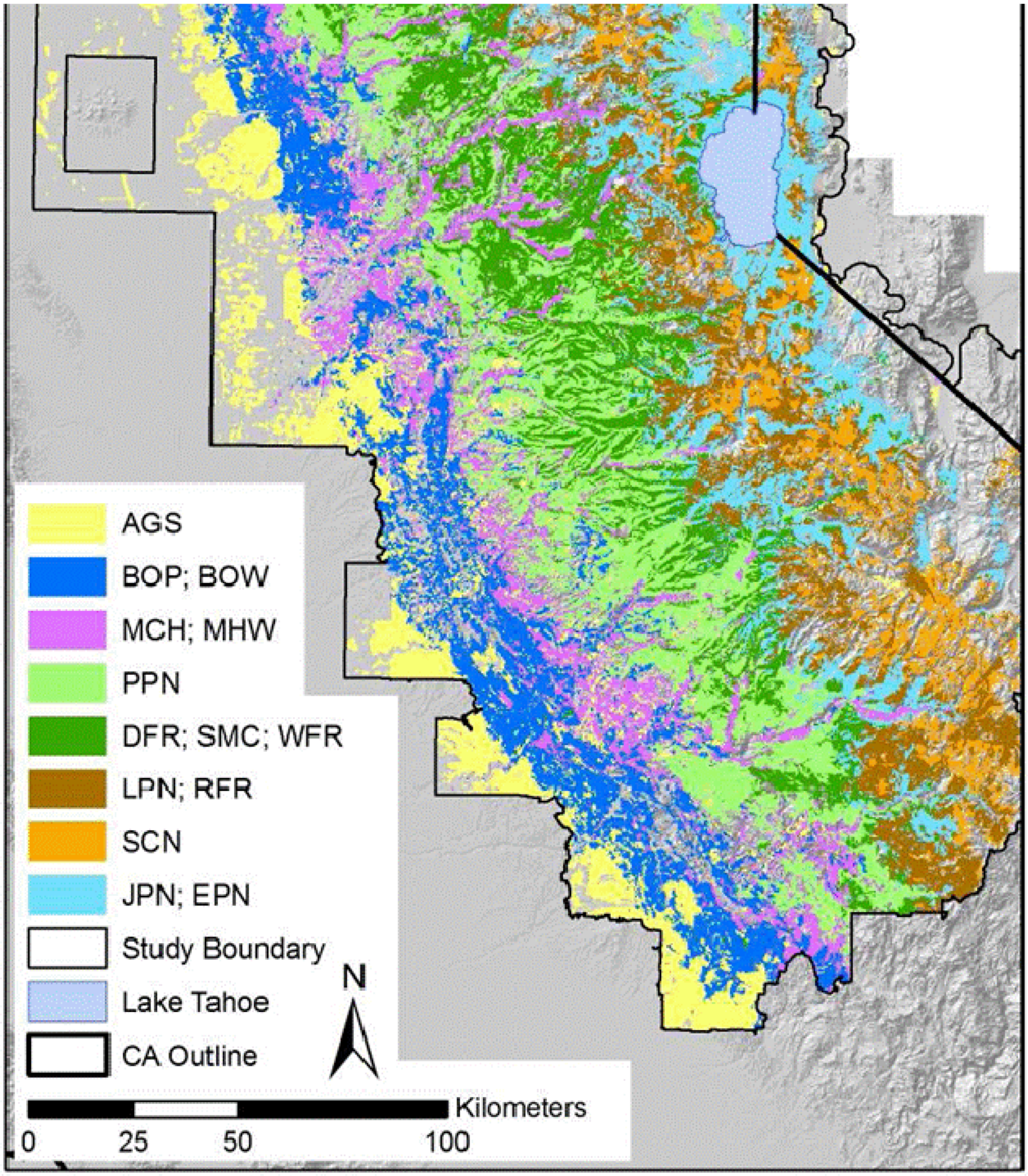


**Figure D6. (A) Distribution of major vegetation types in the central and northern Sierra Nevada in the period 1932-1936.**
*Mapped by the US Forest Service "Wieslander" mapping project. Maps digitized and vegetation types cross-walked to CWHR type by UC-Davis Information Center for the Environment. AGS = agriculture; BOP = blue oak/foothill pine; BOW = blue oak woodland; MCH = mixed conifer hardwood; MHW = mixed hardwood; PPN = ponderosa pine; DFR = Douglas-fir; SMC = Sierra mixed conifer; WFR = white fir; LPN = lodgepole pine; RFR = red fir; SCN = Subalpine conifer; JPN = Jeffrey pine; EPN = eastside pine.*

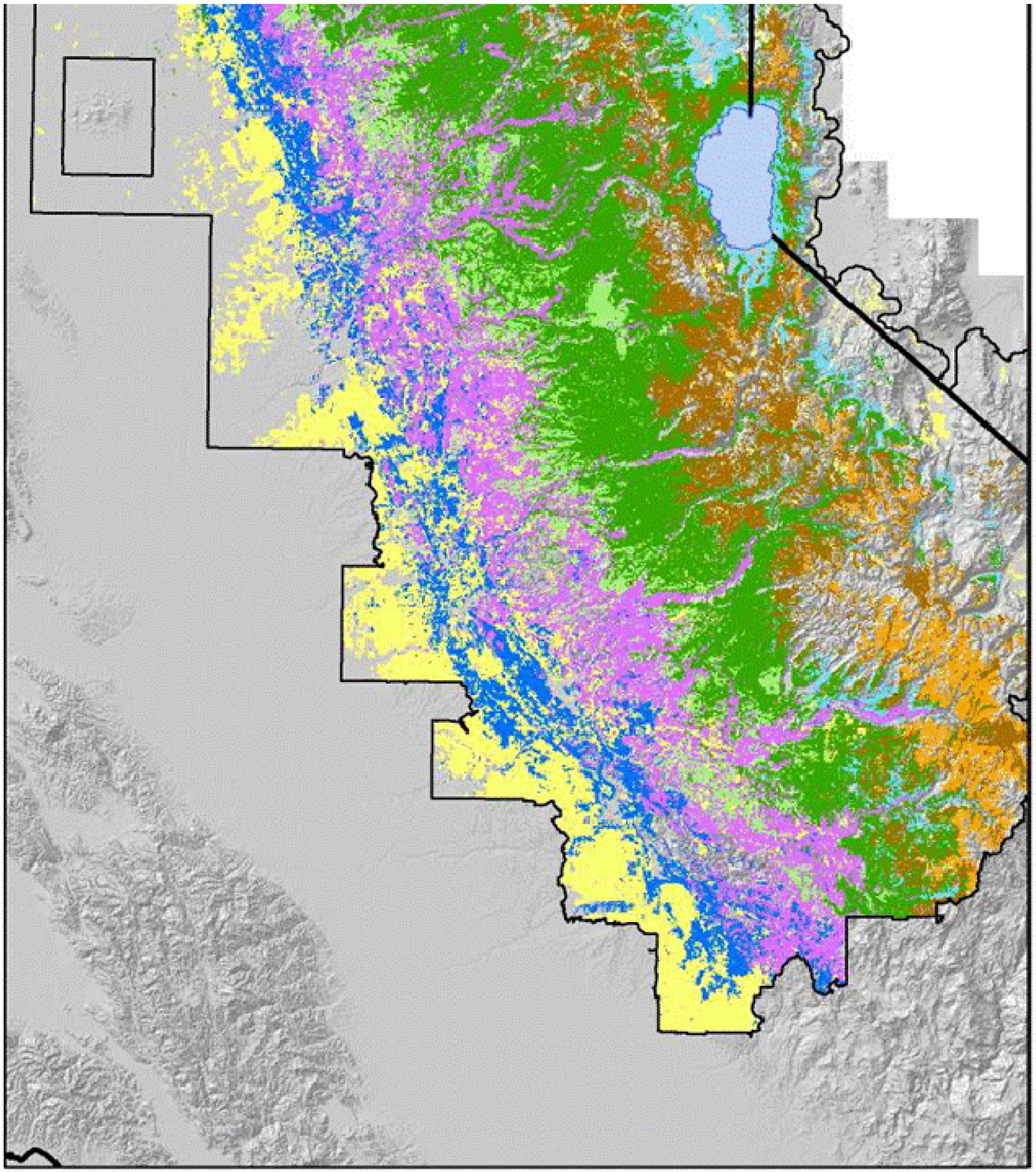

**Figure D6. (B) Distribution of major vegetation types in the central and northern Sierra Nevada in 2000.** *Mapped by the US Forest Service Pacific Southwest Region Remote Sensing Laboratory. See Fig. 6 (A) for key and scale. The major patterns of change between 1934 and 2000 are: (1) loss of yellow pine (ponderosa and Jeffrey pine) dominated forest; (2) expansion of shade tolerant conifers (DFR, WFR, SMC); (3) loss of blue oak woodland; (4) increase in hardwood dominated forests; (5) loss of subalpine and alpine vegetation.*

### Wildlife

Between 1914 and 1920, the Museum of Vertebrate Zoology (MVZ) at the University of California Berkeley surveyed the terrestrial vertebrate fauna at 41 sites along a transect that extended from the western slope of Yosemite National Park to an area near Mono Lake (Grinnell and Storer 1924). In the past decade, MVZ resurveyed the Yosemite transect to evaluate the near century-long changes in Yosemite's vertebrate fauna across this elevation gradient, stretching across numerous vegetation types (Mortiz 2007, Moritz et al. 2008). By comparing earlier and recent MVZ small mammal surveys, Moritz et al. (2008) came to several conclusions: (1) the elevation limits of geographic ranges shifted primarily upward, (2) several high-elevation species (e.g., alpine chipmunk; Tamias alpinus) exhibited range contraction (shifted their lower range limit upslope), while several low-elevation species expanded their range upslope, (3) many species showed no change in their elevational range, (4) elevational range shifts resulted in minor changes in species richness and composition at varying spatial scales, (5) closely-related species responded idiosyncratically to changes in climate and vegetation, and (6) most upwards range shifts for high-elevation species is consistent with predicted climate warming, but changes in most lower- to mid-elevation species' ranges are likely the result of landscape-level vegetation dynamics related primarily to fire history.

Similar distribution patterns have been observed for other faunal taxa throughout the Sierra Nevada. Forister et al. (2010) tracked 159 species of butterflies over 35 years in the central Sierra Nevada and observed upwards shifts in the elevational range of species, a pattern consistent with a warming climate. Tingley et al. (2009) resurveyed bird distributions along the Grinnell transects in the entire Sierra Nevada and concluded that 91% of species tracked changes in temperature or precipitation over time and 26% of species tracked both temperature and precipitation. This suggests that birds move in response to changing climates in order to maintain environmental associations to which they are adapted. The authors also suggest that combining climate and niche models may be useful for predicting future changes in regional bird distributions (Tingley et al. 2009). In contrast with other faunal studies, Drost and Fellers (1996) found that most frog and toad species in Yosemite exhibited widespread decline over the past several decades, regardless of elevation. Primary factors contributing to this faunal collapse throughout the Sierra Nevada include introduced predators, a fungal pathogen, pesticides, and climate change (Wake and Vredenburg 2008).

# III. Future predictions

## Climate

### *Statewide models*

Relatively few future-climate modeling efforts have treated areas as restricted as the State of California. The principal limiting factor is the spatial scale of the General Circulation Models (GCMs) that are used to simulate future climate scenarios. Most GCMs produce raster outputs with pixels that are 10,000's of km2 in area. To be used at finer scales, these outputs must be downscaled using a series of algorithms and assumptions – these finer-scale secondary products currently provide the most credible sources we have for estimating potential outcomes of long- term climate change for California. Another complication is the extent to which GCMs disagree with respect to the probable outcomes of climate change. For example, a recent comparison of 21 published GCM outputs that included California found that estimates of future precipitation ranged from a 26% increase per 1º C increase in temperature to an 8% decrease (Gutowski et al. 2000, Hakkarinen and Smith 2003). That said, there was some broad consensus: all of the reviewed GCMs predicted warming temperatures for California, and 13 of 21 predicted higher precipitation (three showed no change and five predicted decreases). According to Dettinger (2005), the most common prediction among the most recent models (which are considerably more complex and, ideally, more credible) is temperature warming by about 9° F by 2100, with precipitation remaining similar or slightly reduced compared to today. Most models agreed that summers will be drier than they are currently, regardless of levels of annual precipitation.

The most widely cited of the recent California-wide modeling efforts is probably Hayhoe et al. (2005). Hayhoe et al. (2005) used two contrasting GCMs (much warmer and wetter, vs. somewhat warmer and drier) under low and high greenhouse gas emissions scenarios to make projections of climate change impact for California over the next century. By 2100, under all GCM x emissions scenarios, April 1 snowpack was down by -22% to -93% in the 6,700-10,000 feet elevation belt, and the date of peak snowmelt was projected to occur from 3 to 24 days earlier in the season. Average temperatures were projected to increase by 2 to 4 degrees F in the winter, and 4-8 degrees in the summer. Finally, three of the four GCM x emissions scenarios employed by Hayhoe et al. (2005) predicted strong decreases in annual precipitation by 2100, ranging from -91 to -157%; the remaining scenario predicted a 38% increase.

*Local models*

Until recently, no studies had projected future climates specifically for the area of the Lake Tahoe Basin. Coats et al. (2010) downscaled the GFDL and PCM General Circulation Models (GCMs) from the original 100 x 100 km output grid to a 12 x 12 km grid and provided 21st century projections of future climate and hydrology trends for the LTB based on the IPCC A2 (strong increase in Greenhouse gases [GHGs]) and B1 (moderate increase in GHGs) emissions scenarios. Coats et al.'s (2010) results project strong upward trends in maximum and minimum emperatures, with an increase of up to 9°F by 2100 under the A2 emissions scenario (the equivalent of dropping the elevation of the LTB by over 2500 feet), but no strong trends in annual precipitation amount, except for a slight drying trend projected by the GFDL-A2 scenario toward the end of the century. Coats et al. (2010) also project a continuing shift from snowfall to rain (from about 35% snowfall currently to 10-18% by 2100).

## Hydrology

*Sierra Nevada*

Miller et al. (2003) modeled future hydrological changes in California as a function of two contrasting GCMs (the same GCMs used in Hayhoe et al. [2005] and Lenihan et al. [2003; see below]) and a variety of scenarios intermediate to the GCMs. Miller et al. (2003) found that annual streamflow volumes were strongly dependent on the precipitation scenario, but changes in seasonal runoff were more complex. Predicted spring and summer runoff was lower in all of the California river basins they modeled, except where precipitation was greatly increased, in which case runoff was unchanged from today (Miller et al. 2003). Runoff in the winter and early spring was predicted to be higher under most of the climate scenarios because higher temperatures cause snow to melt earlier. Flood potential in California rivers that are fed principally by snowmelt (e.g., streams in and around Lake Tahoe) was predicted to increase under all scenarios of climate change, principally due to earlier dates of peak daily flows and the increase in the proportion of precipitation falling as rain. These increases in peak daily flows are predicted under all climate change scenarios, including those assuming reduced precipitation (Miller et al. 2003). The predicted increase in peak flow was most pronounced in higher elevation river basins, due to the greater reliance on snowmelt. If precipitation does increase, streamflow volumes during peak runoff could greatly increase. Under the wettest climate scenario modeled by Miller et al. (2003), by 2100 the volume of flow during the highest flow days could more than double in many Sierra Nevada rivers. This would result in a substantial increase in flood risk in flood-prone areas like Sacramento or Reno. According to Miller et al. (2003), increased flood risk is a high probability outcome of the continuation of current climate change trends, because temperature, not precipitation, is the main driver of higher peak runoff. If scales, these outputs must be downscaled using a series of algorithms and assumptions – these finer-scale secondary products currently provide the most credible sources we have for climate change leads not only to an increase in average precipitation but also a shift to more extreme precipitation, then peak flows would be expected to increase even more.

*Lake Tahoe Basin*

In their recent assessment of potential climate change and hydrology trends in the Lake Tahoe Basin, Coats et al. (2010) project a continuing trend toward earlier snowmelt and runoff during the water year; increases in drought severity, especially toward the end of the century; and dramatic increases in flood magnitude in the middle third of the century, especially under the B1 emissions scenario. Current snowpack duration in the LTB is between 240 and 250 days. Under the most extreme future climate x emissions scenario (GFDL-A2), Coats et al. (2010) project a mean snowpack duration of only 184 days by the last third of the 21st century. The same scenario projects a loss in stream inflow into Lake Tahoe of 20-40% of baseline (average of 1967-1999) by 2100.

## Vegetation

Lenihan et al. (2003, 2008) used a dynamic ecosystem model ("MC1") which estimates the distribution and the productivity of terrestrial ecosystems such as forests, grasslands, and deserts across a grid of 100 km2 cells. To this date, this is the highest resolution at which a model of this kind has been applied in California, but it is not of high enough resolution to be applied to the Lake Tahoe Basin as a unit. Based on their modeling results, Lenihan et al. (2003, 2008) projected that forest types and other vegetation dominated by woody plants in California would migrate to higher elevations as warmer temperatures make those areas suitable for colonization and survival. For example, with higher temperatures and a longer growing season, the area occupied by subalpine and alpine vegetation was predicted to decrease as evergreen conifer forests and shrublands migrate to higher altitudes (Fig. D7). Under their "wet future" scenarios, Lenihan et al. (2003, 2008) projected a general expansion of forests in northern California. With higher rainfall and higher nighttime minimum temperatures, broadleaf trees (especially oak species) were predicted to expand their distribution in many parts of the Sierra Nevada, and conifer-dominated forests were predicted to decrease in extent in the same areas. Under their "dry future" scenarios, Lenihan et al. (2003, 2008) predicted that grasslands would expand throughout the state, and that increases in the extent of tree-dominated vegetation would be minimal (Fig. 7). An expansion of shrublands into conifer types was also predicted, due to drought and increases in fire frequency and severity (see below). Hayhoe et al. (2005) also used the MC1 ecosystem model to predict vegetation and ecosystem changes under a number of different future greenhouse gas emissions scenarios. Their results were qualitatively similar to the Lenihan et al. (2003, 2008) results.

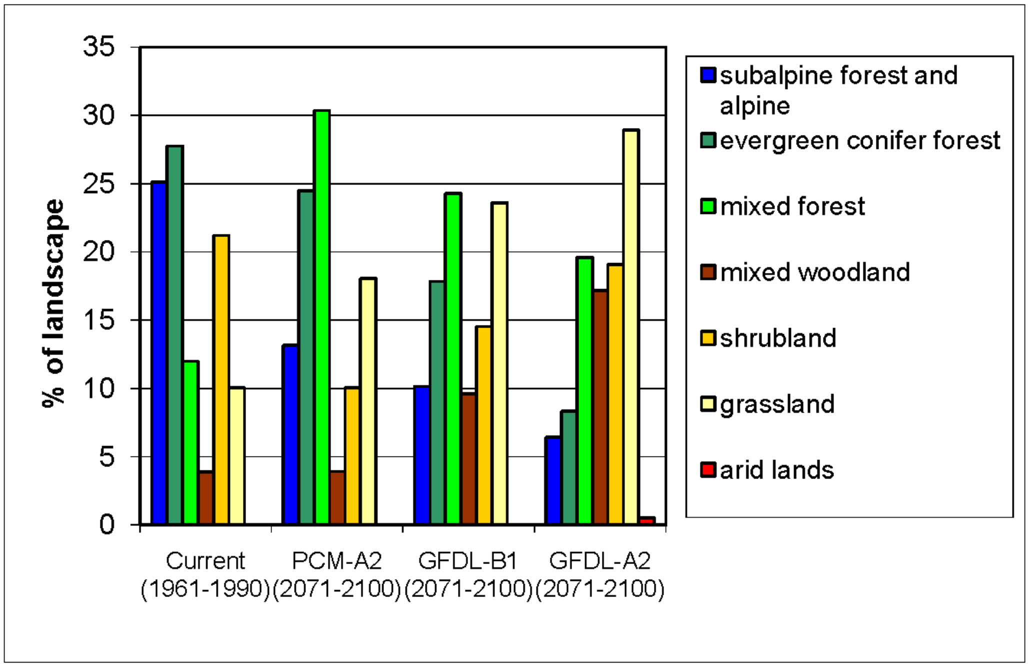


**Figure D7. MC1 outputs for the Sierra Nevada Ecological Section, current vs. future projections of vegetation extent.**
*The LTBMU is found within this Ecological Section. The GFDL-B1 scenario = moderately drier than today, with a moderate temperature increase (<5.5° F); PCM-A2 = similar ppt. to today, with <5.5° temp. increase; GFDL-A2 = much drier than today and much warmer (>7.2° higher) All scenarios project significant loss of subalpine and alpine vegetation. Most scenarios project lower cover of shrubland (including west side chaparral and east side sagebrush), due principally to increasing frequencies and extent of fire. Large increases in the hardwood component of forests are projected in all scenarios. Large increases in cover of grassland are projected for the Section, principally at lower elevations. Conifer forest decreases in cover under all scenarios. From Lenihan et al. (2008).*

## Fire

The combination of warmer climate with higher CO2 fertilization will likely cause more frequent and more extensive fires throughout western North America (Price and Rind 1994, Flannigan et al. 2000); fire responds rapidly to changes in climate and will likely overshadow the direct effects of climate change on tree species distributions and migrations (Flannigan et al. 2000, Dale et al. 2001). A temporal pattern of climate-driven increases in fire activity is already apparent in the western United States (Westerling et al. 2006), and modeling studies specific to California expect increased fire activity to persist and possibly accelerate under most future climate scenarios, due to increased growth of fuels under higher CO2 (and in some cases precipitation), decreased fuel moistures from warmer dry season temperatures, and possibly increased thundercell activity (Price and Rind 1994, Miller and Urban 1999, Lenihan et al. 2003,2008; Westerling and Bryant 2006). By 2100, Lenihan et al.'s (2003, 2008) simulations suggest a c. 5% to 8% increase in annual burned area across California, depending on the climate scenario (Fig. 8). Increased frequencies and/or intensities of fire in coniferous forest in California will almost certainly drive changes in tree species compositions (Lenihan et al. 2003, 2008), and will likely reduce the size and extent of late-successional refugia (USFS and BLM 1994, McKenzie et al. 2004). Thus, if fire becomes more active under future climates, there may be significant repercussions for old growth forest and old growth-dependent flora and fauna.

A key question is to what extent future fire regimes in montane California will be characterized by either more or less severe fire than is currently (or was historically) the case. Fire regimes are driven principally by the effects of weather/climate and fuel type and availability (Bond and van Wilgen 1996). 70 years of effective fire suppression in the American West have led to fuel-rich conditions that are conducive to intense forest fires that remove significant amounts of biomass (McKelvey et al. 1996, Arno and Fiedler 2005, Miller et al. 2009), and most future climate modeling predicts climatic conditions that will likely exacerbate these conditions. Basing their analysis on two GCMs under the conditions of doubled atmospheric CO2 and increased annual precipitation, Flannigan et al. (2000) predicted that mean fire severity in California (measured by difficulty of control) would increase by about 10% averaged across the state. Vegetation growth models that incorporate rising atmospheric CO2 show an expansion of woody vegetation on many western landscapes (Lenihan et al. 2003, Hayhoe et al. 2005), which could feedback into increased fuel biomass and connectivity and more intense (and thus more severe) fires. Use of paleoecological analogies also suggests that parts of the Pacific Northwest (including northern California) could experience more severe fire conditions under warmer, more CO2-rich climates (Whitlock et al., 2003). Fire frequency and severity (or size) are usually assumed to be inversely related (Pickett and White 1985), and a number of researchers have demonstrated this relationship for Sierra Nevada forests (e.g. Swetnam 1993, Miller and Urban 1999), but if fuels grow more rapidly and dry more rapidly – as is predicted under many future climate scenarios – then both severity and frequency may increase. In this scenario, profound vegetation type conversion is all but inevitable. Lenihan et al.'s (2003, 2008) results for fire intensity predict that large proportions of the Sierra Nevada landscape may see mean fire intensities increase over current conditions by the end of the century, with the actual change in intensity depending on future precipitation patterns.

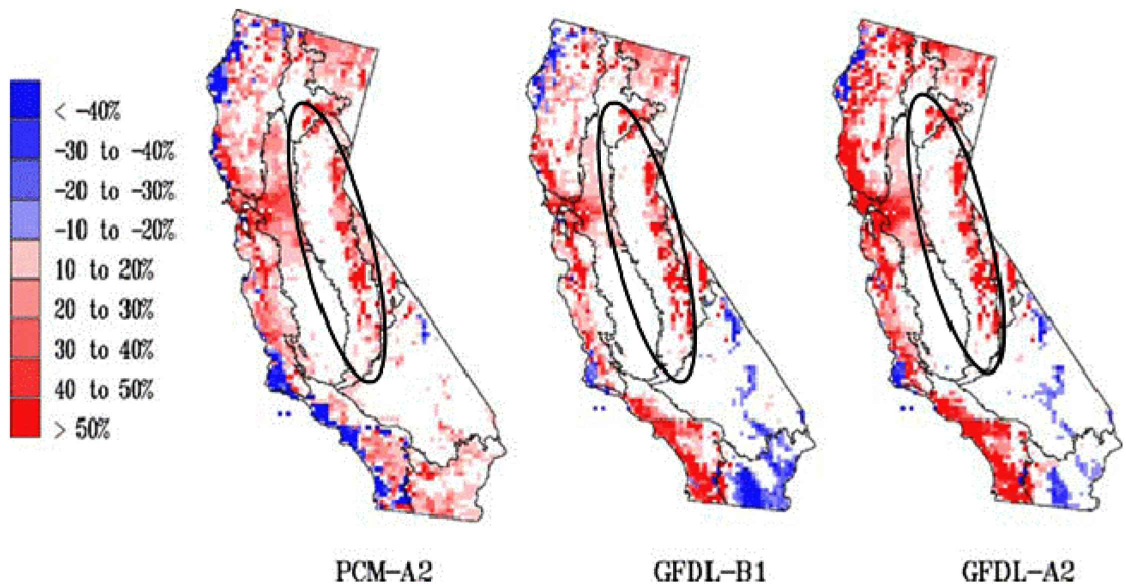


**Figure D8. Percent change in projected mean annual area burned for the 2050-2099 period relative to the mean annual area burned for the historical period (1895-2003).**
*Sierra Nevada is circled. Figure from Lenihan et al. (2008). See Fig. 7 for description of the climate and emissions scenarios (PCM-A2, GFDL- B1, GFDL-A2).*

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